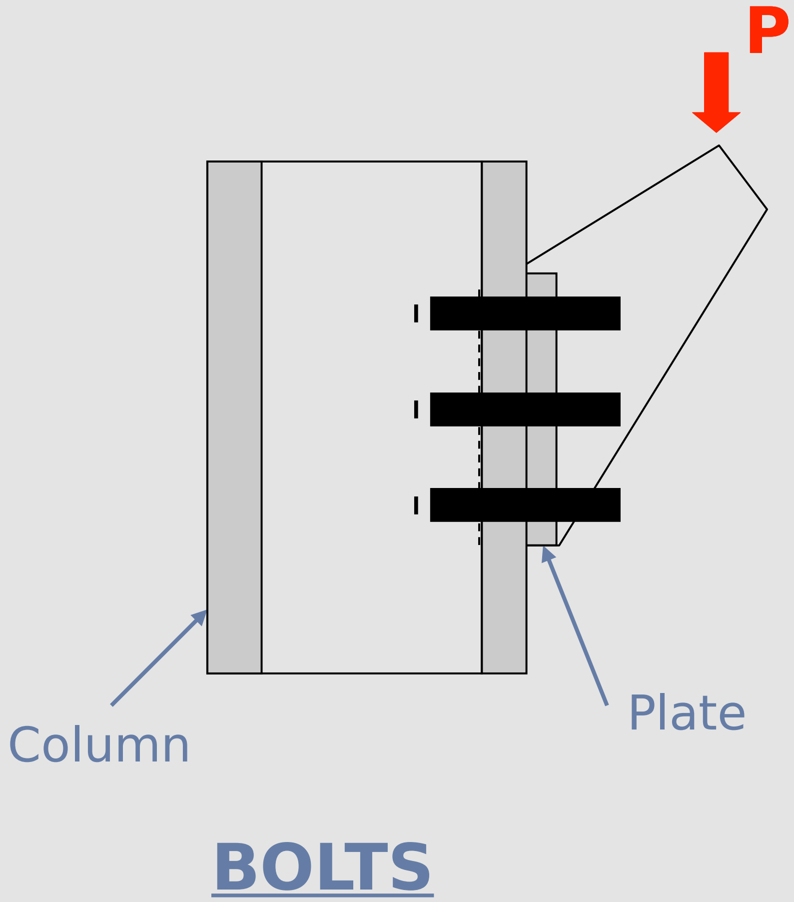
C & EE 141

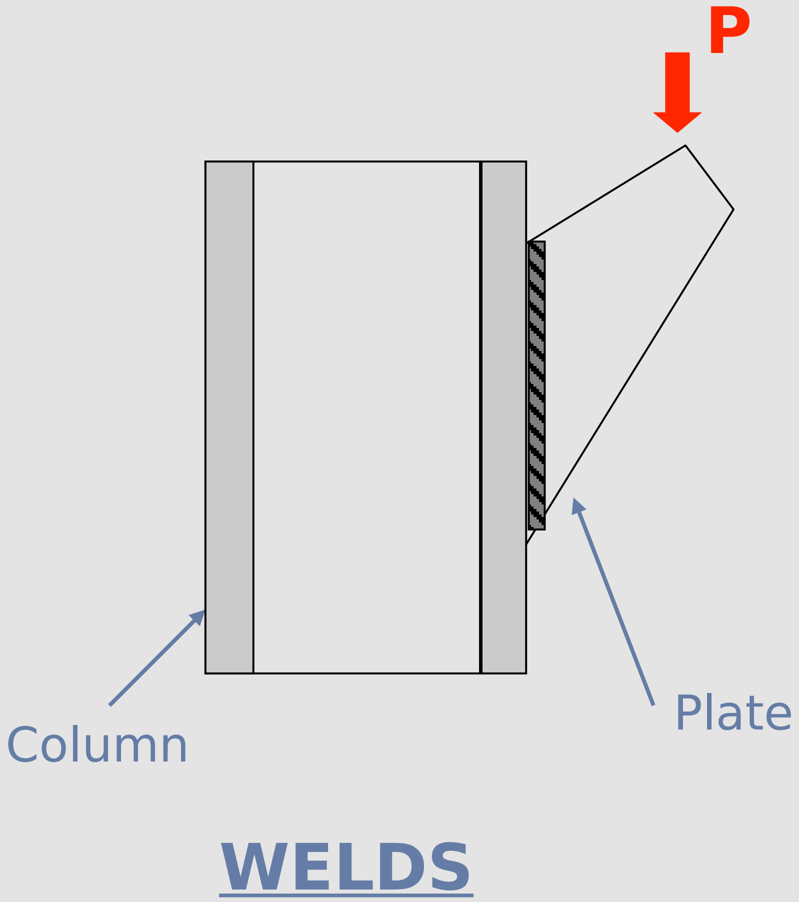
Eccentric Connections

Suggested Reading

- AISC SCM, Section 7
  - Pg. 7-6 to 7-9 (Elastic Method only)
  - Pg. 7-10 to 7-13 (Case II assumption only)
- AISC SCM, Section 8
  - Pg. 8-9, 8-12 to 8-15 (Elastic Method only)
- Reference on CCLE

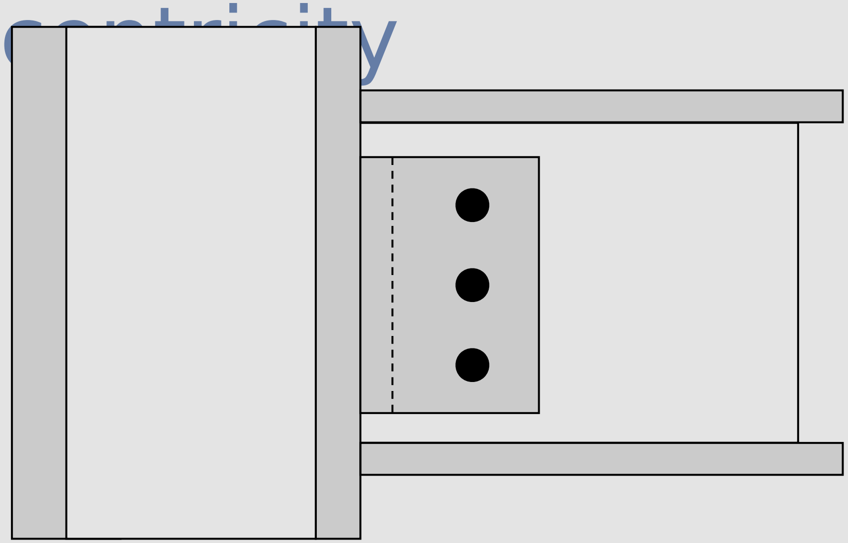
Eccentric Connections



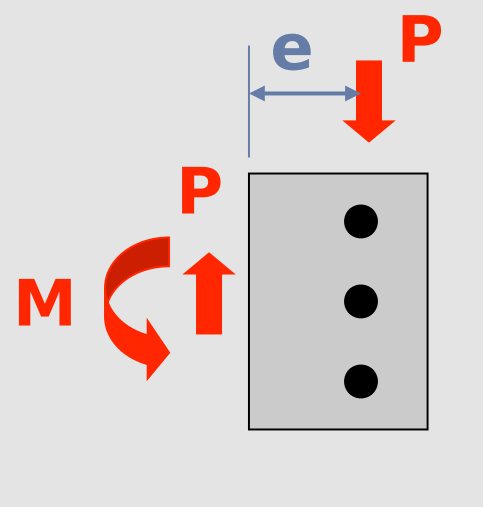


Eccentric Connections

- Occur when the resultant of the applied load does not pass through the C.G. of the connection
- Most connections have some eccentricity



Typ Beam to Column Conn.



FBD of Plate

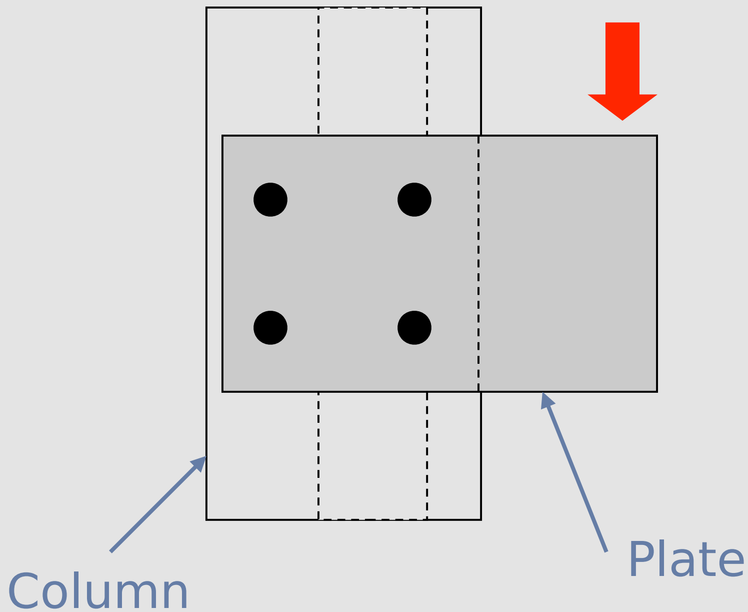
Eccentric Bolted Connections

Bolt Analysis Methods

- Elastic Method
  - Conservative approach
  - Historically used & most commonly used approach
  - Friction between parts ignored
  - Bolts are considered rigid (no deformation)
- Instantaneous Center of Rotation Method
  - Considers deformation at each bolt
  - Better match to actual test results
  - Very tedious to apply
  - Tables in manual may be used (but only if bolt pattern is a match)

We will focus on the Elastic Method only

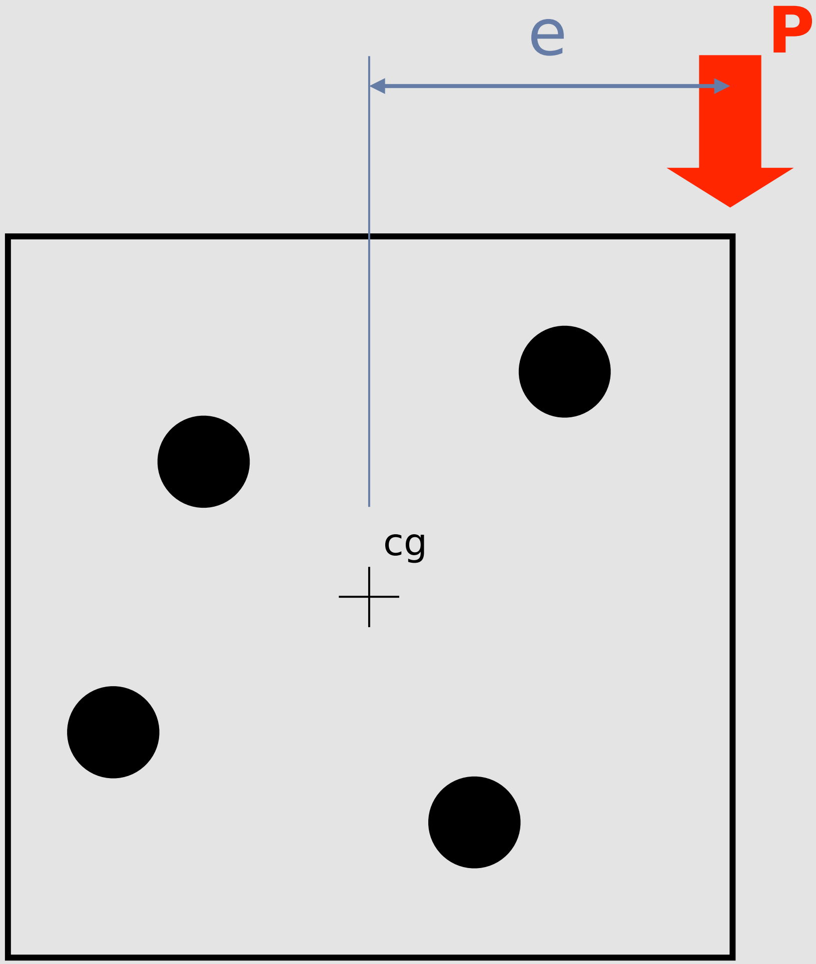
Eccentricity in Plane of Faying Surface



BOLTS

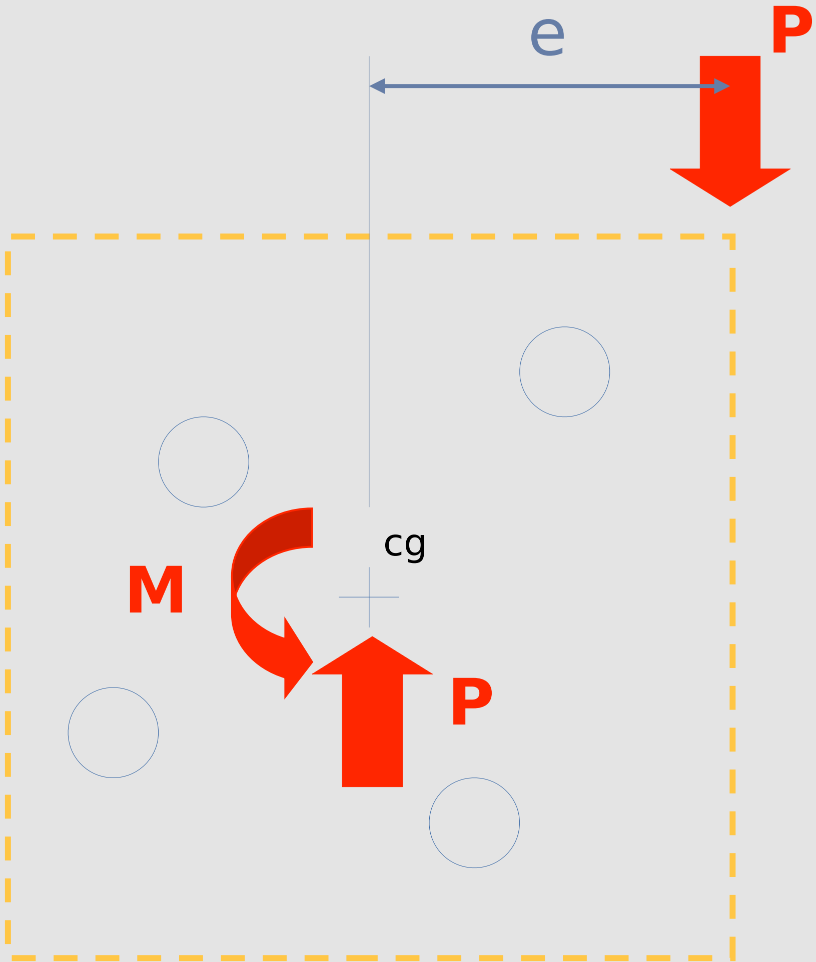
Elastic Method (Ecc. in Plane of Faying Surface)

- Force is applied offset from the C.G. of the bolt group.
  - Eccentricity is in the plane of the faying surface



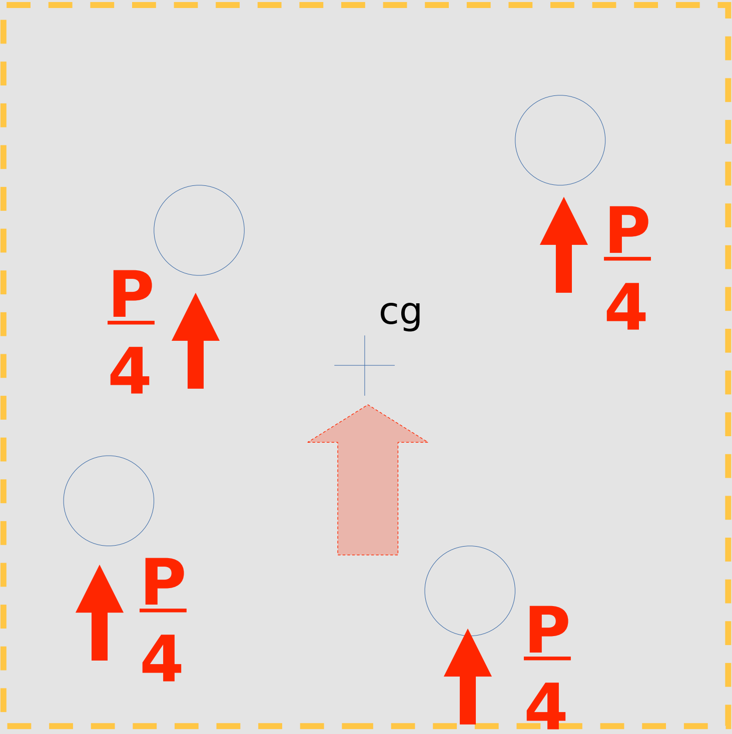
Elastic Method (Ecc. in Plane of Faying Surface)

- Equivalent force-couple occurs at C.G. of bolt group



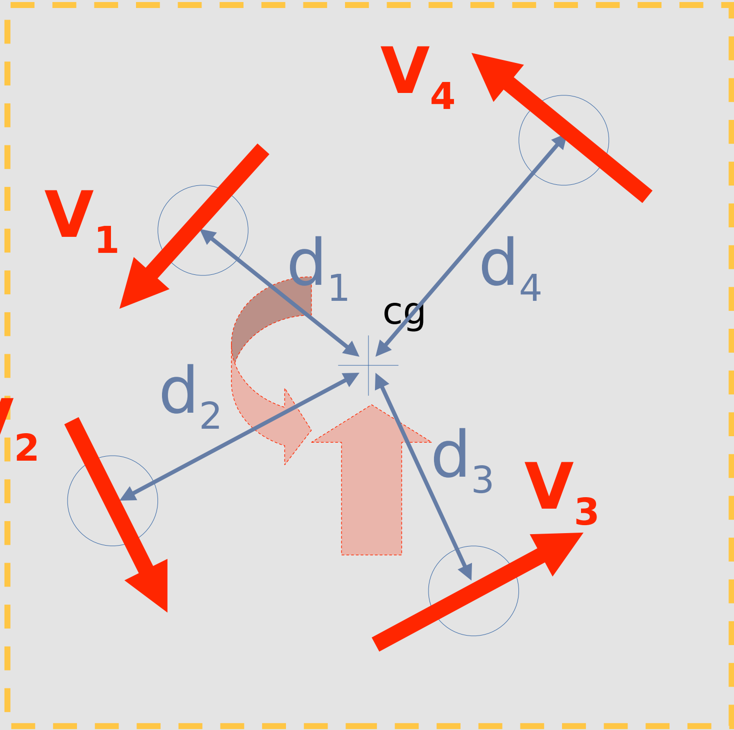
Elastic Method (Ecc. in Plane of Faying Surface)

- Direct shear is shared equally by each of the bolts



Elastic Method
(Ecc. in Plane of Faying Surface)

- Moment is resisted by shear in each bolt in proportion to each bolt’s distance from the C.G.
- Shear due to moment is normal to radial vector from C.G.

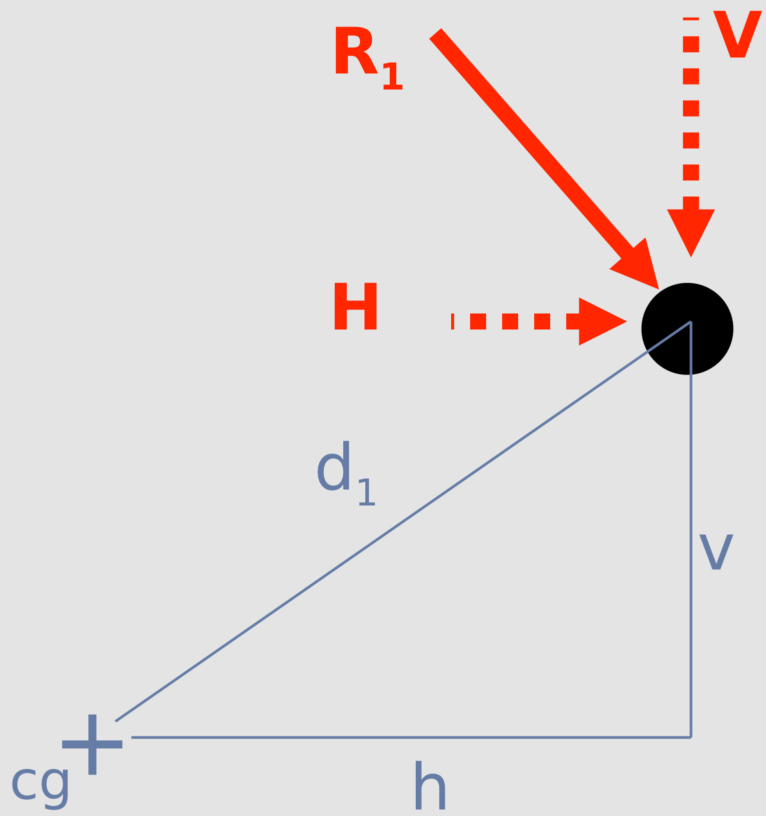


Elastic Method (Ecc. in Plane of Faying Surface)

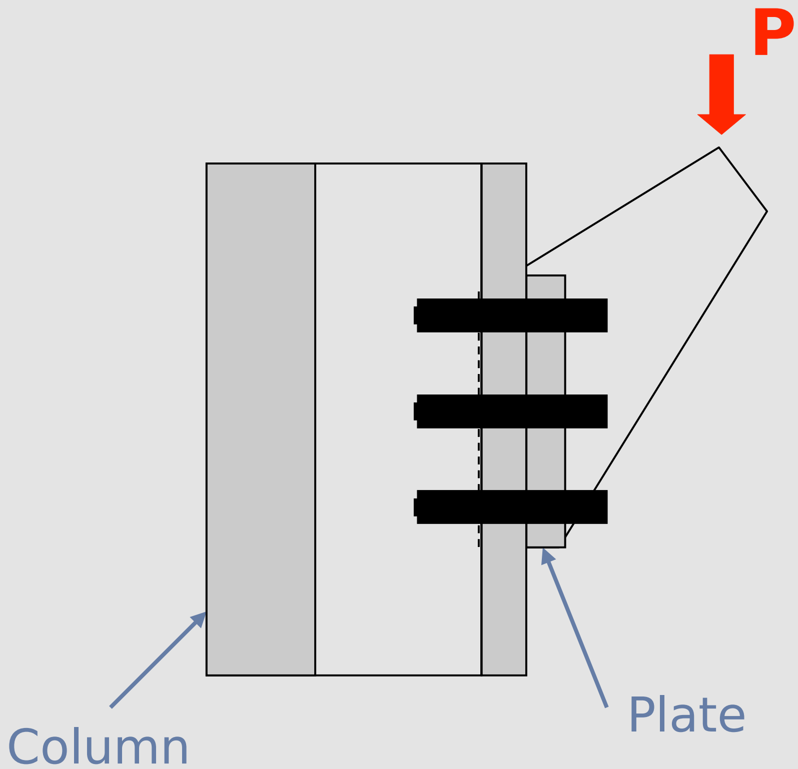
$$H_{bolt} = \frac{P_h}{n} + \frac{Mv}{\sum d^2}$$

$$V_{bolt} = \frac{P_v}{n} + \frac{Mh}{\sum d^2}$$

$$R_{bolt} = \sqrt{H_{bolt}^2 + V_{bolt}^2}$$



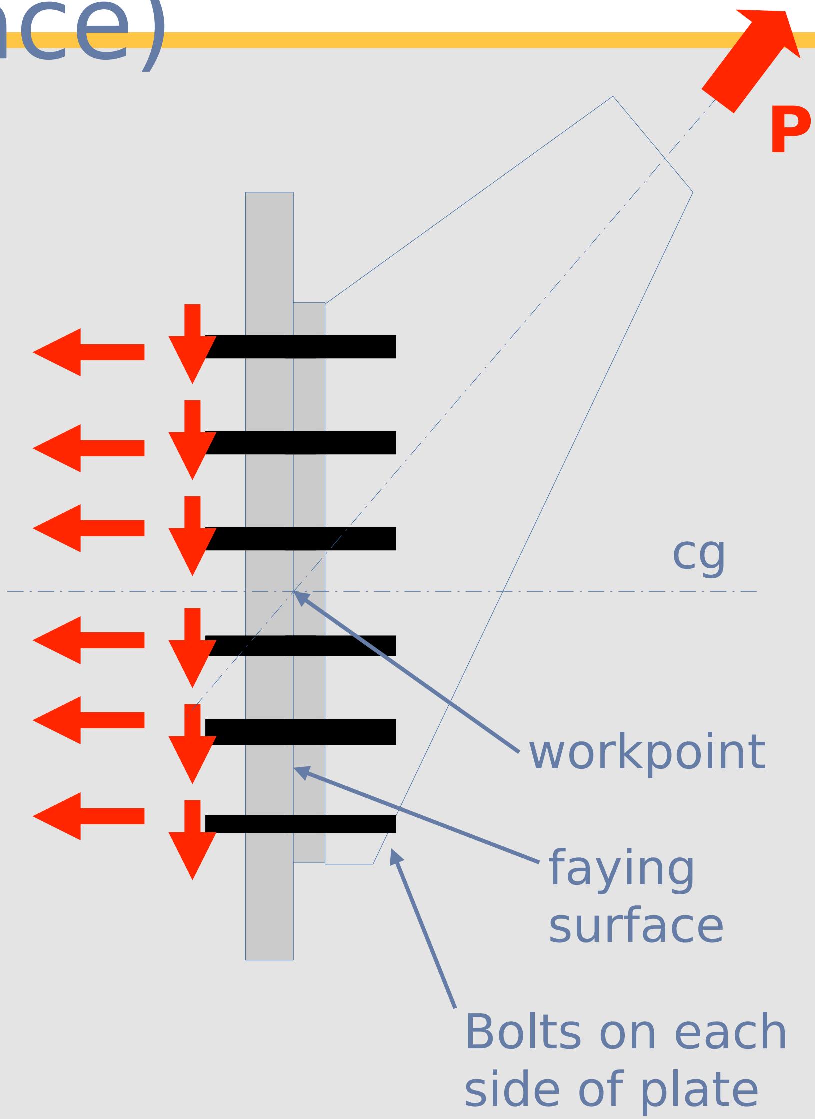
Combined Shear & Tension (Ecc. Normal to Plane of Faying Surface)



BOLTS

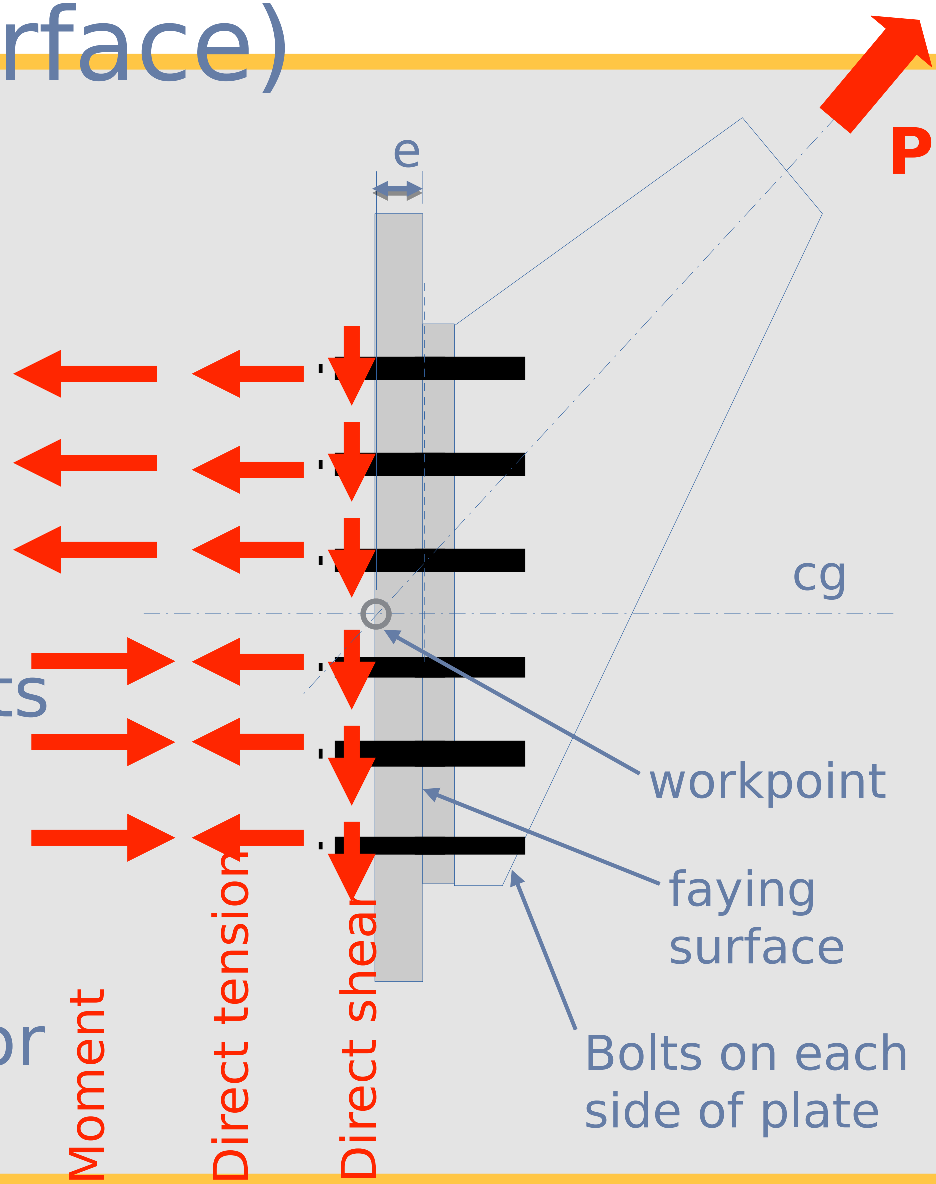
Combined Shear & Tension (Ecc. Normal to Plane of Faying Surface)

- When work point of force is at C.G. of bolt group:
  - Direct tension and shear forces are shared equally by each of the bolts



Case II Analysis (Ecc. Normal to Plane of Faying Surface)

- When work point of force is eccentric normal to the faying surface:
  - Direct tension and shear are shared equally between bolts
  - Moment due to eccentricity is resisted using a <u>plastic</u> distribution for tension (Case II



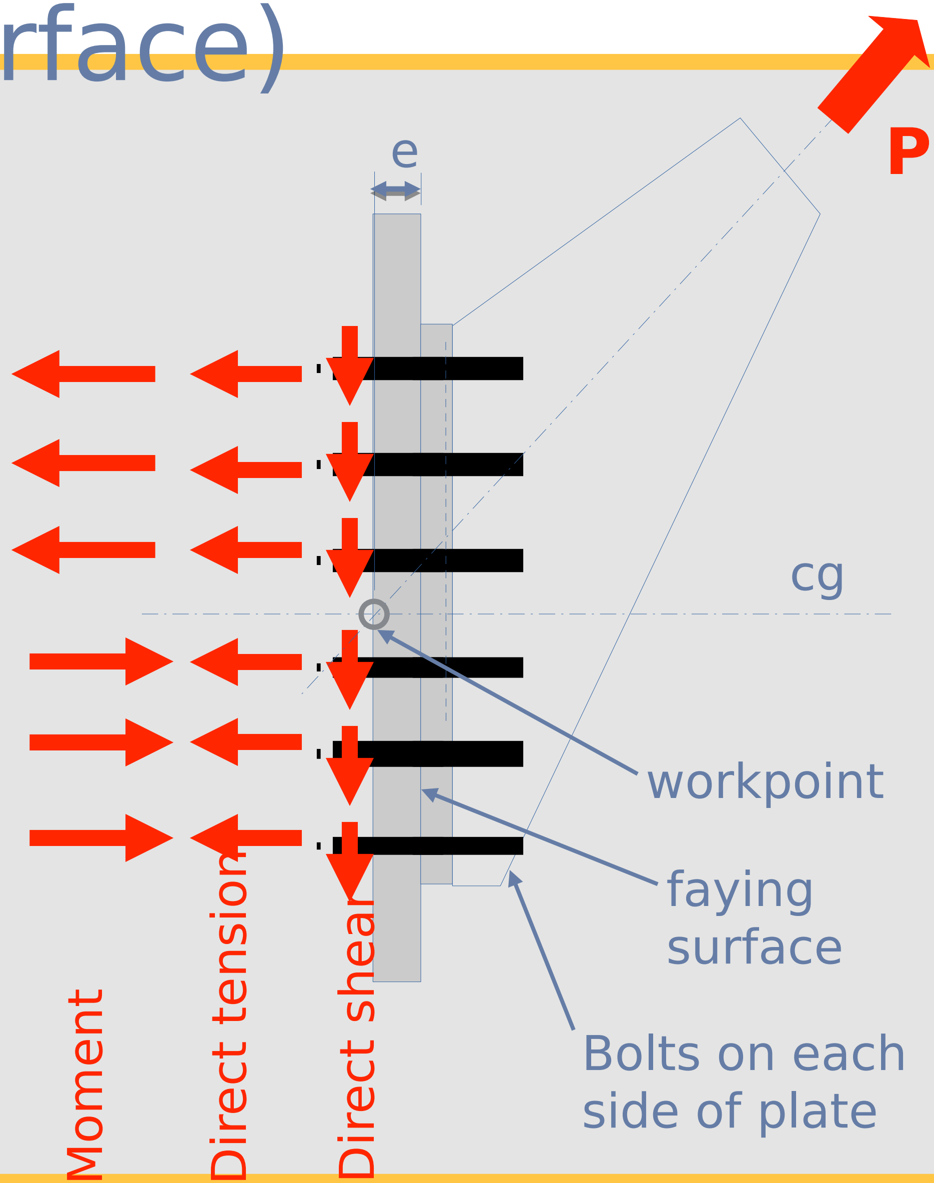
Case II Analysis (Ecc. Normal to Plane of Faying Surface)

$$V_{bolt} = \frac{P_v}{n}$$

$$T_{bolt} = \frac{P_h}{n} + \frac{P_v e}{n' d_m}$$

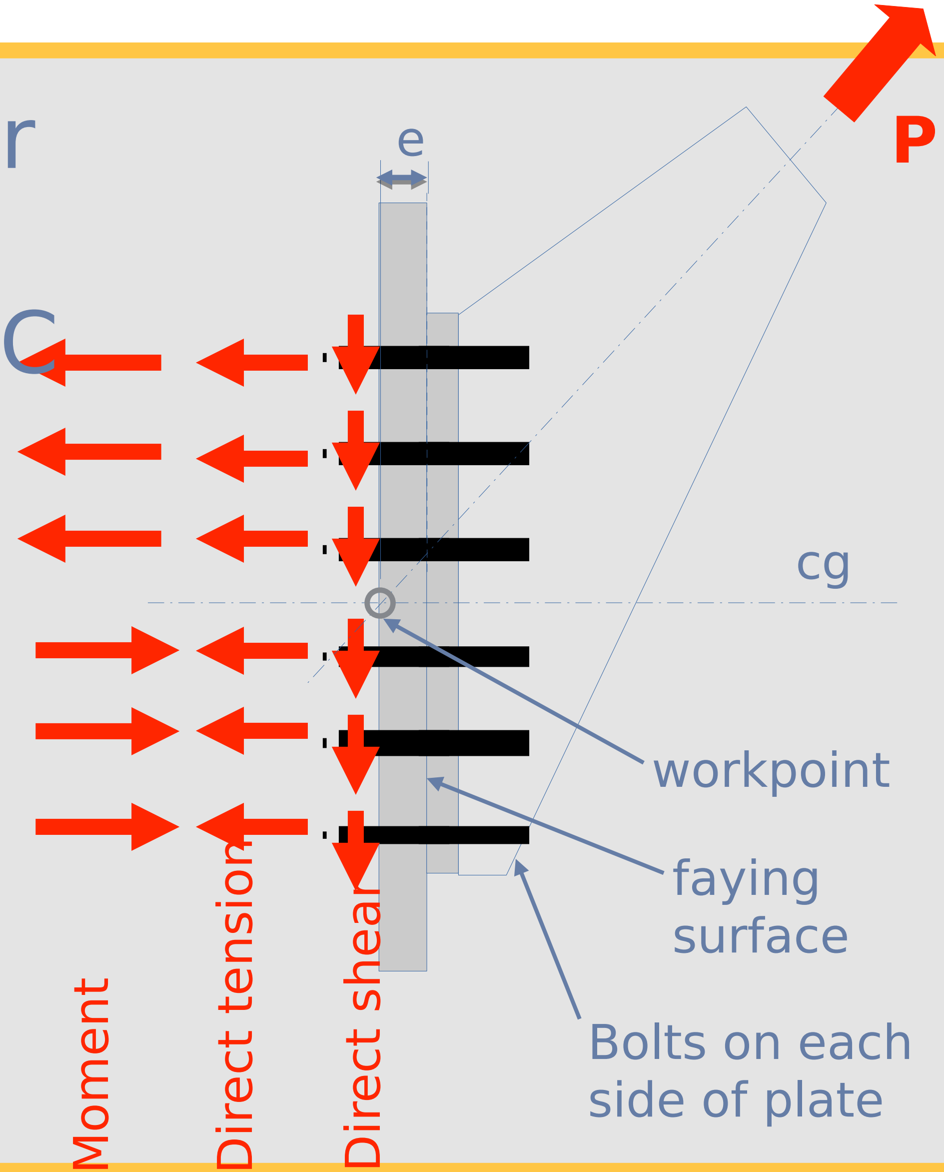
n’ = number of bolts above/below the neutral axis

d_m = moment arm between resultant tensile force and resultant compressive force (for moment component)



Combined Shear & Tension

- Consider bolt shear and tension interaction per AISC
  - J3.7 for bearing
  - J3.9 for S.C.



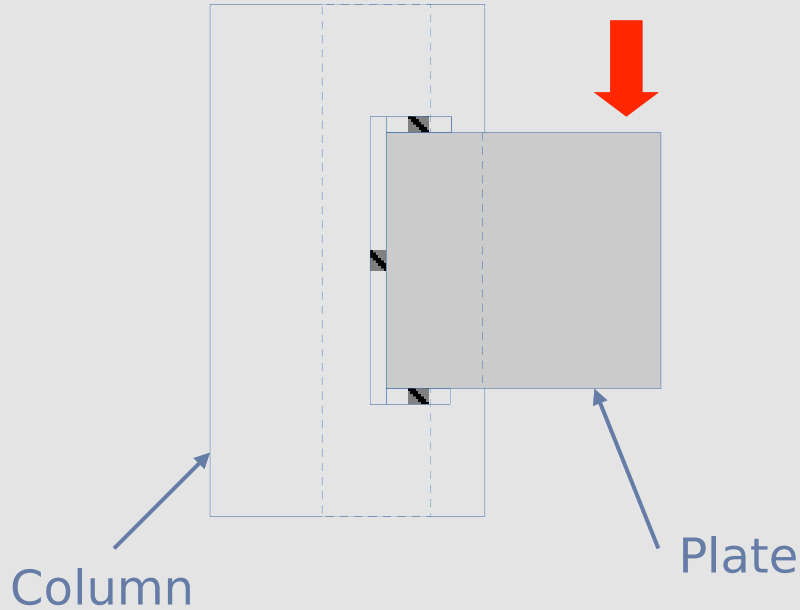
Eccentric Welded Connections

Weld Analysis Methods

- Elastic Method
  - Conservative approach
  - Historically used & most commonly used approach
  - Assumes only deformation in the welds
  - Connected pieces considered rigid
- Instantaneous Center of Rotation Method
  - Considers load-deformation relationship of weld which varies with angle of load from axis of weld (θ)
  - Less conservative but more tedious to apply
  - Tables in manual are useful (but only if weld pattern is a match)

We will focus on the Elastic Method only

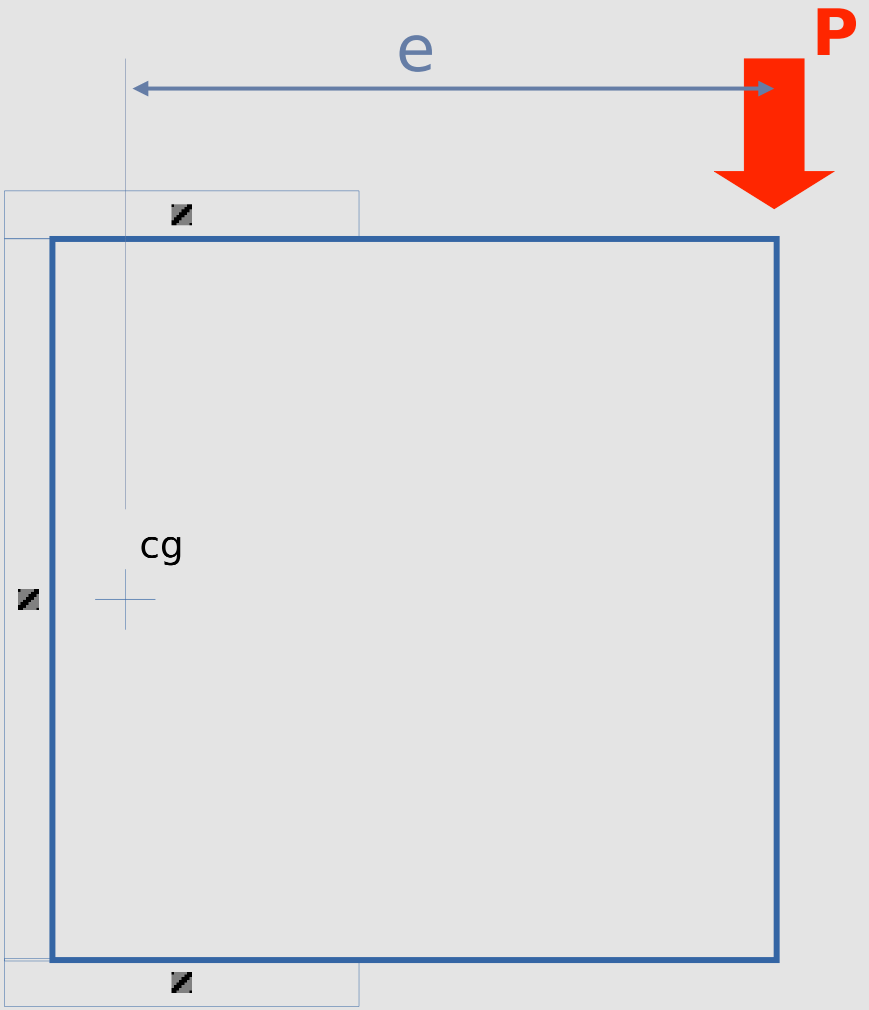
Combined Shear (Ecc. in Plane of Faying Surface)



WELDS

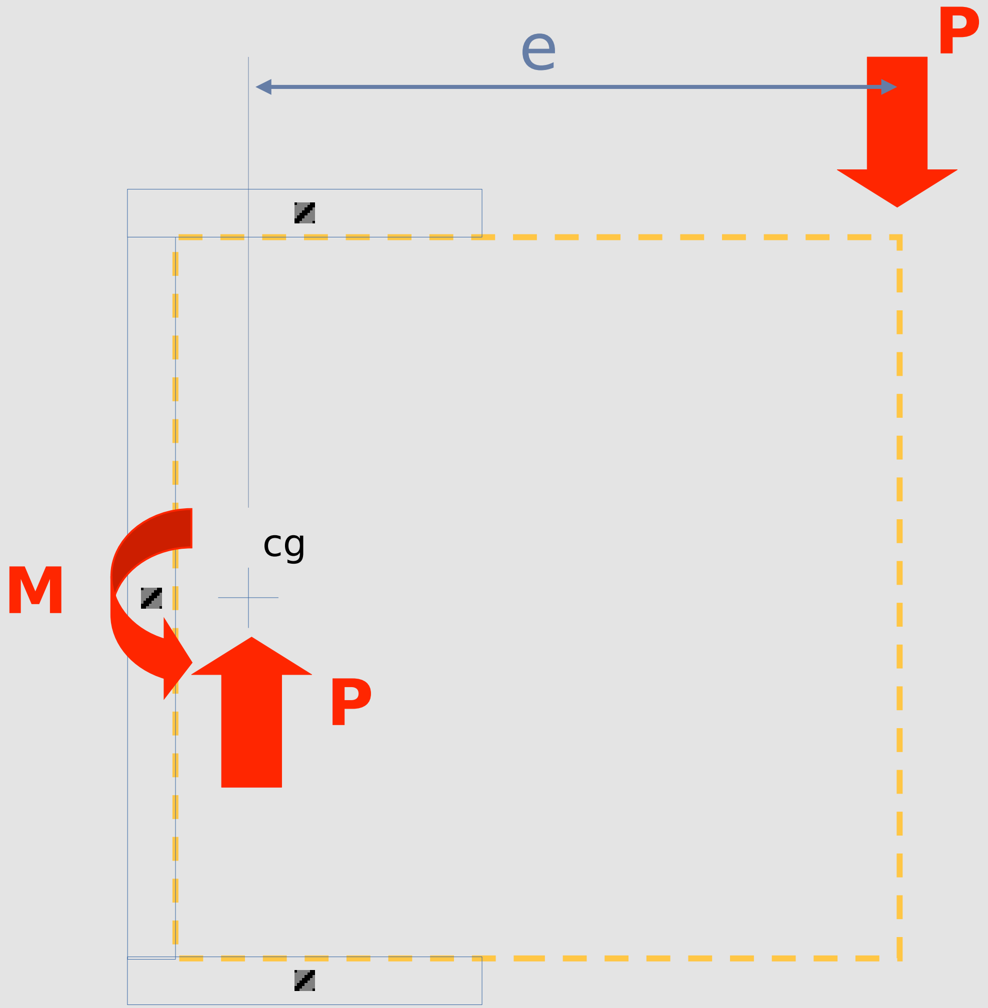
Elastic Method
(Ecc. in Plane of Faying Surface)

- Force is applied offset from the C.G. of the weld



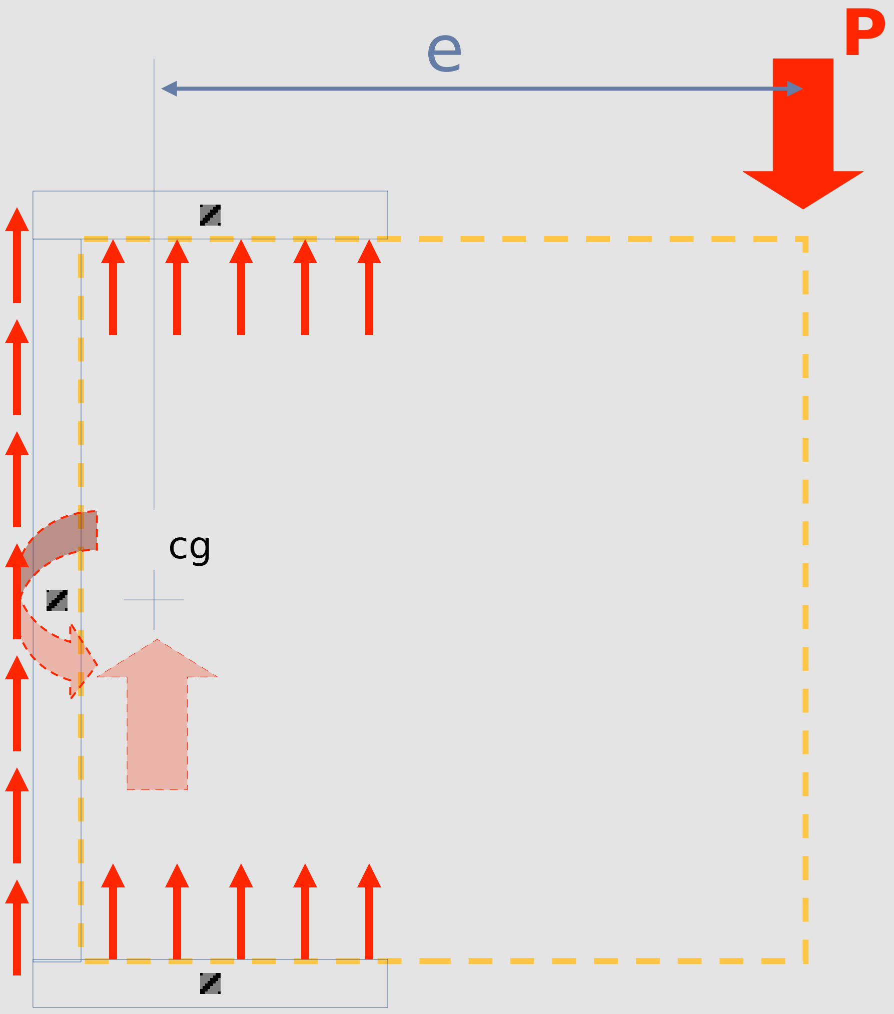
Elastic Method (Ecc. in Plane of Faying Surface)

- Equivalent force-couple occurs at C.G. of weld



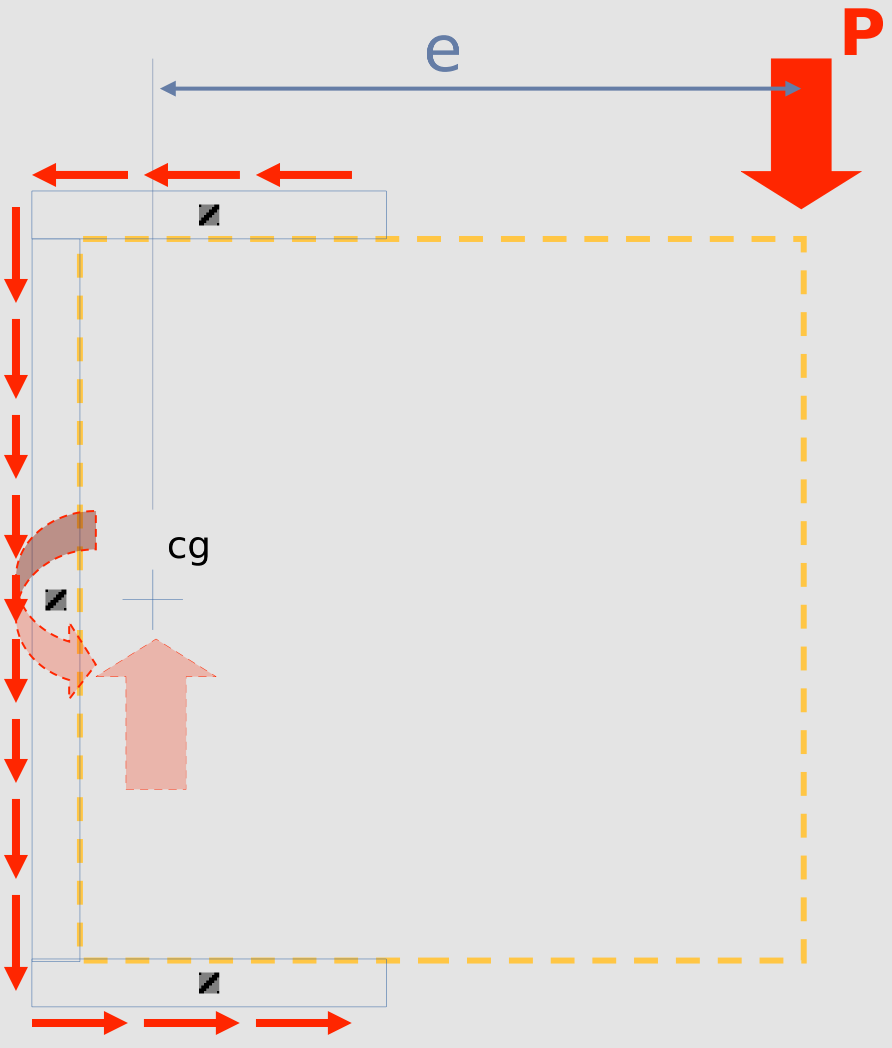
Elastic Method (Ecc. in Plane of Faying Surface)

- Direct shear is distributed evenly along the length of the weld



Elastic Method
(Ecc. in Plane of Faying Surface)

- Moment resisted in proportion to the of distance from the C.G. of the weld (elastic distribution)



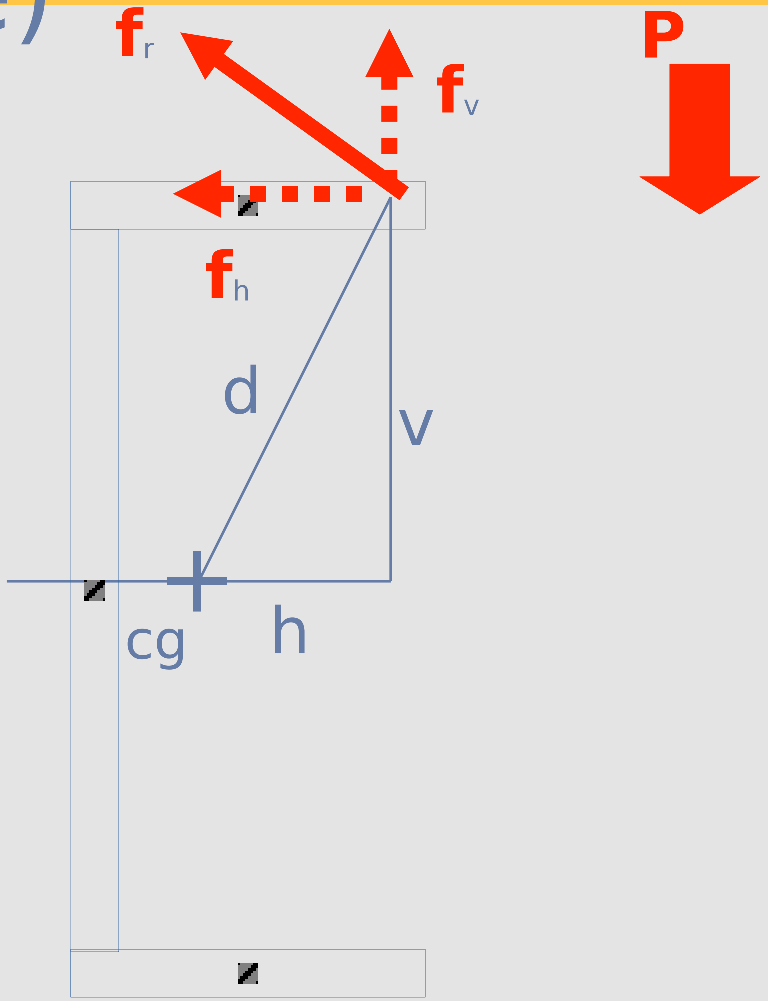
Elastic Method (Ecc. in Plane of Faying Surface)

$$f_h = \frac{P_h}{L_w} + \frac{Mv}{I_p}$$ [kip/in]

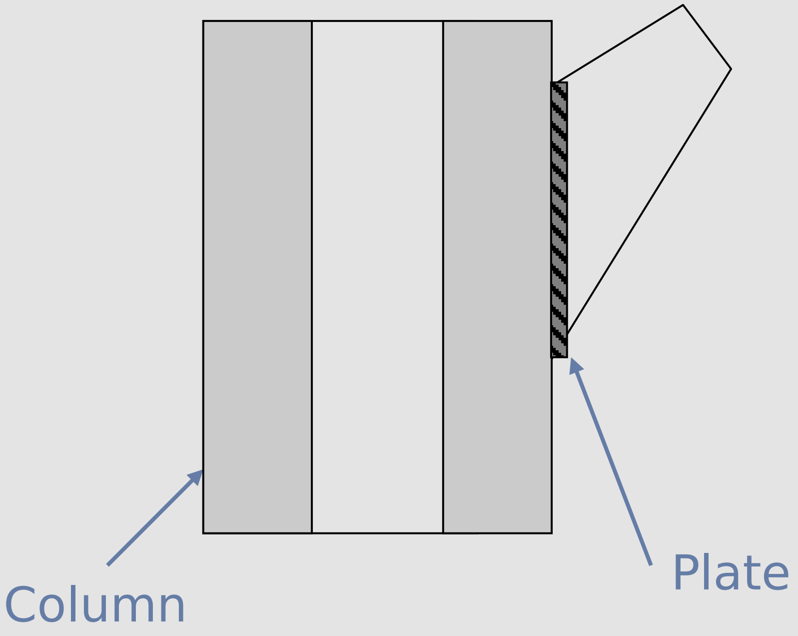
$$f_v = \frac{P_v}{L_w} + \frac{Mh}{I_p}$$ [kip/in]

$$f_r = \sqrt{f_v^2 + f_h^2}$$ [kip/in]

$$I_p = I_x + I_y$$ [in³]



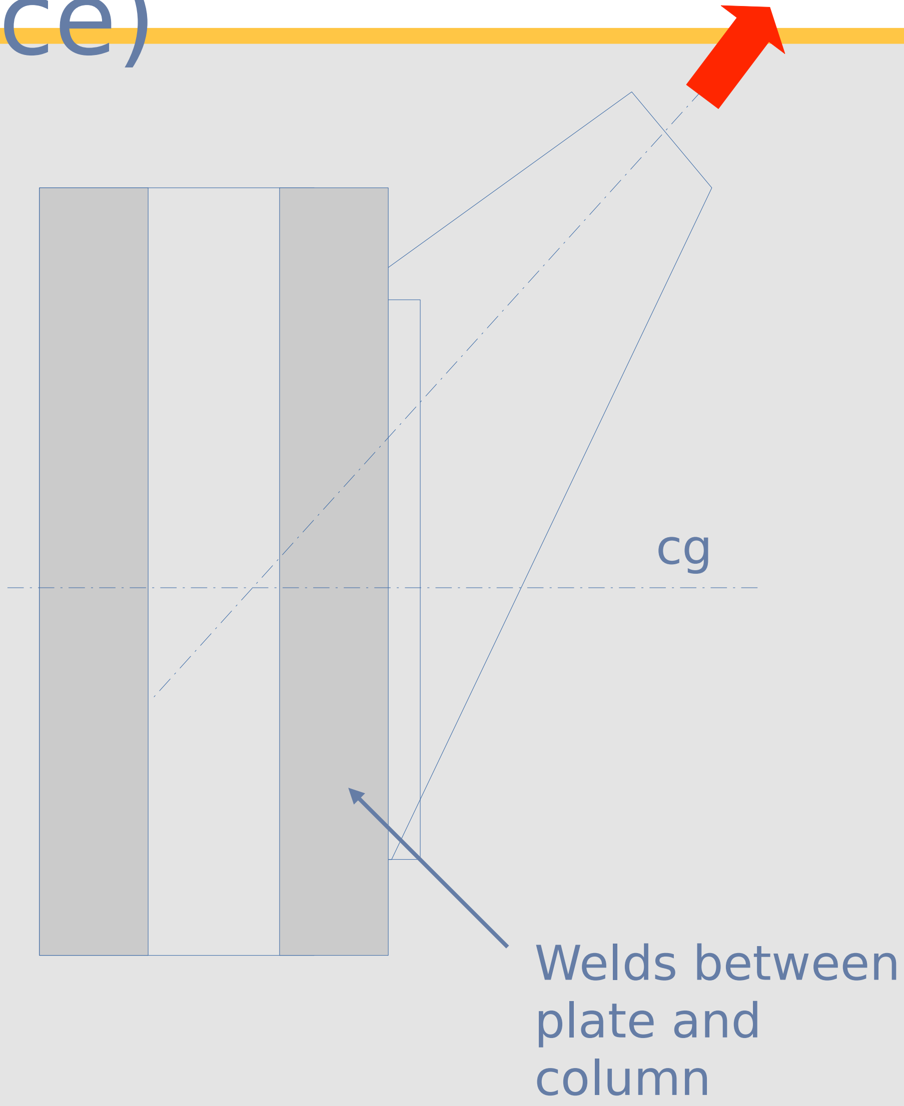
Elastic Method (Ecc. Normal to Plane of Faying Surface)



WELDS

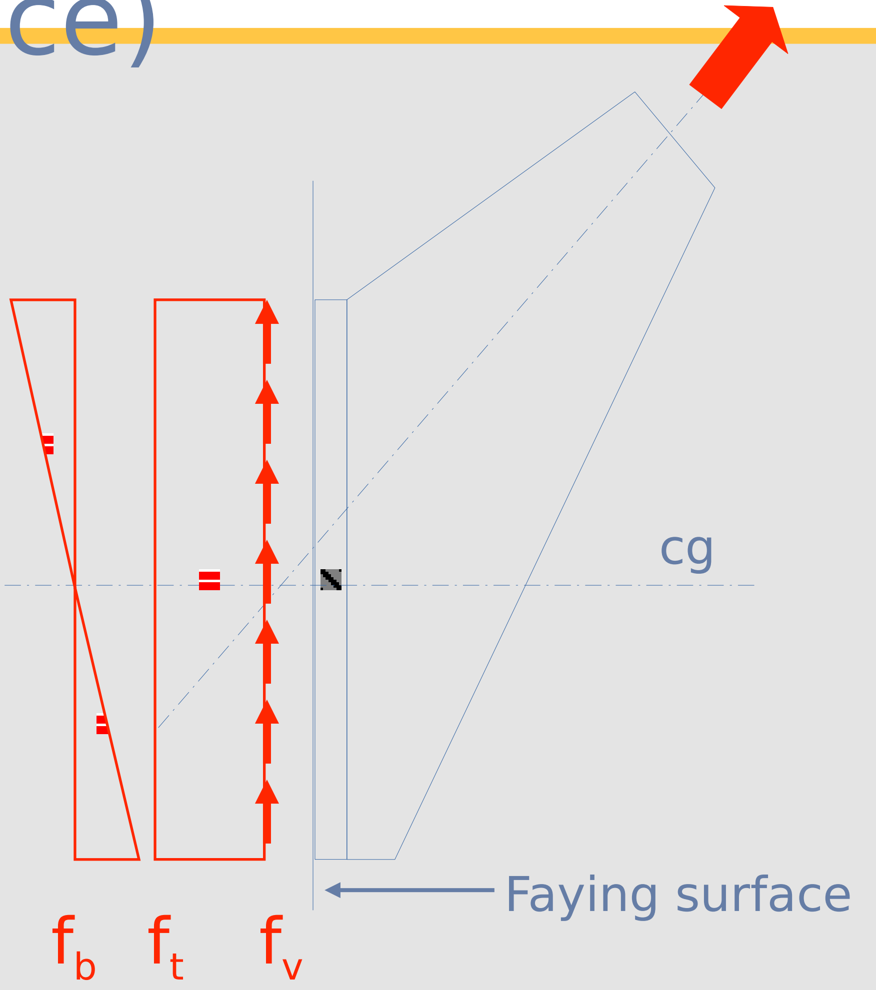
Elastic Method (Ecc. Normal to Plane of Faying Surface)

- Shear force is distributed uniformly along the weld length
- Direct tensile force is distributed uniformly along the weld length
- Bending moment is distributed to weld based on elastic distribution (distance from C.G.)
- No tension-shear interaction, as in bolts. Design for resultant shear



Elastic Method (Ecc. Normal to Plane of Faying Surface)

- Shear force is distributed uniformly along the weld length
- Direct tensile force is distributed uniformly along the weld length
- Bending moment is distributed to weld based on elastic distribution (distance from C.G.)



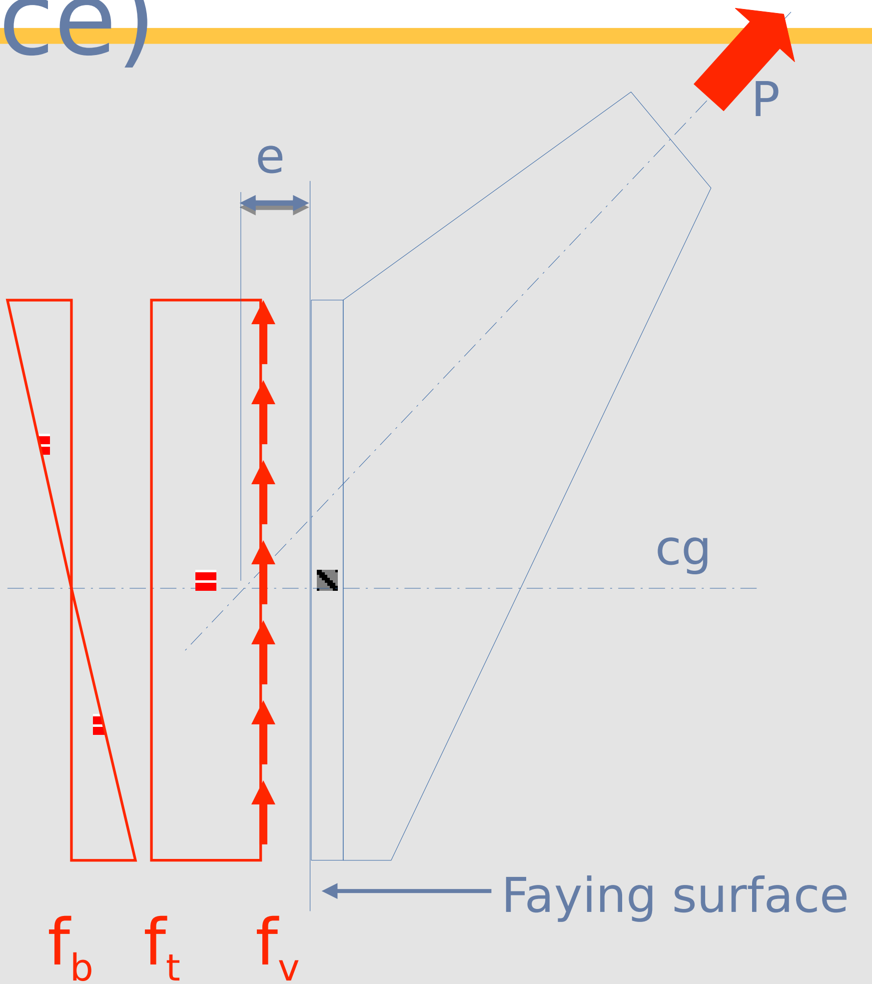
Elastic Method (Ecc. Norm. to Plane of Faying Surface)

$$f_t = \frac{P_h}{L_w} \qquad f_v = \frac{P_v}{L_w}$$

$$f_b = \frac{My}{I} = \frac{P_h e}{I}$$

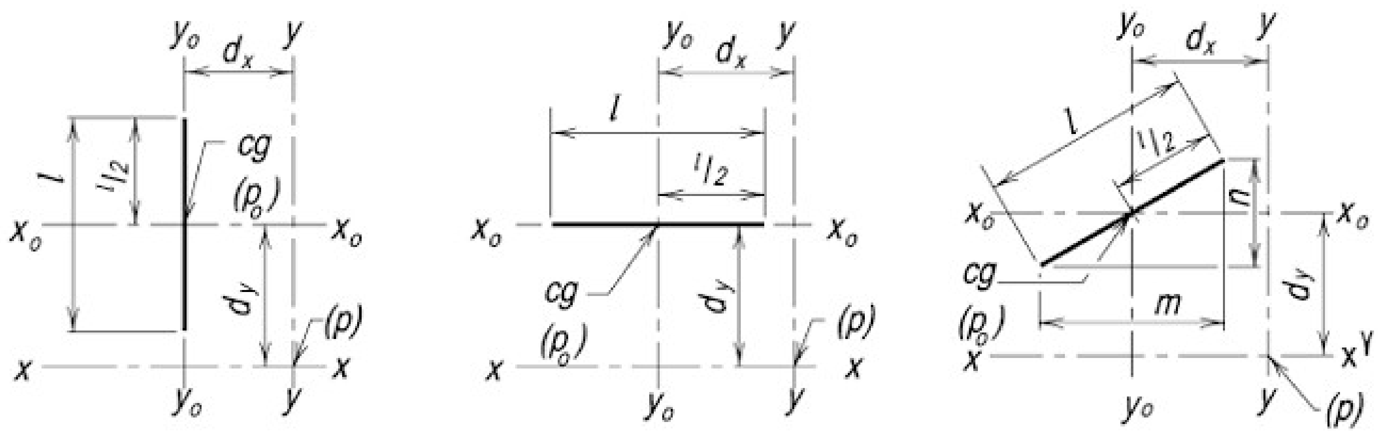
$$f_r = \sqrt{f_v^2 + \left(f_t + f_b\right)^2}$$

Units of f_r are [kip/in]



Section Properties of Weld Groups

- AISC SCM Pg. 8-13

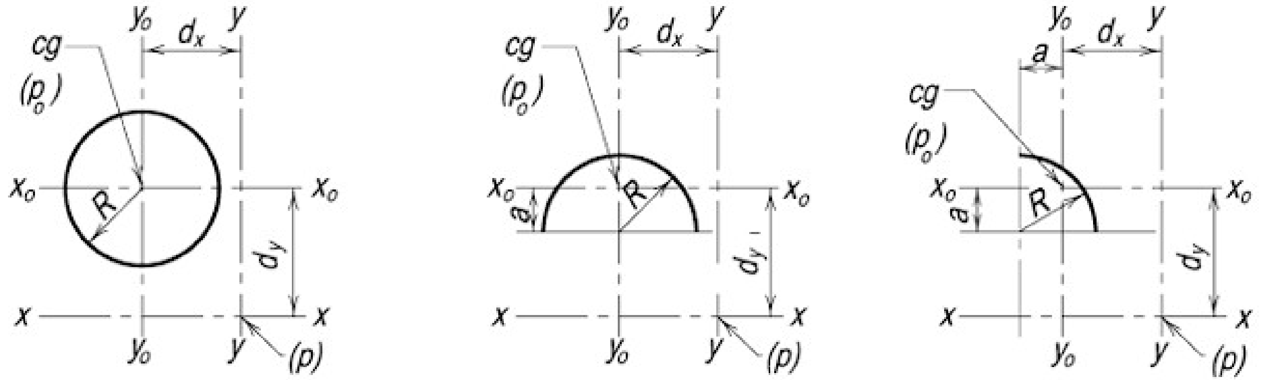


$$I_{xo} = \frac{l^3}{12}$$
$$I_x = \frac{l^3}{12} + l(d_y)^2$$
$$I_{yo} = 0$$
$$I_y = l(d_x)^2$$

$$I_{xo} = 0$$
$$I_x = l(d_y)^2$$
$$I_{yo} = \frac{l^3}{12}$$
$$I_y = \frac{l^3}{12} + l(d_x)^2$$

$$I_{xo} = \frac{ln^2}{12}$$
$$I_x = \frac{ln^2}{12} + l(d_y)^2$$
$$I_{yo} = \frac{lm^2}{12}$$
$$I_y = \frac{lm^2}{12} + l(d_x)^2$$

Section Properties of Weld Groups



$l = 6.283R$

$a = 0.637R$
$l = 3.14R$

$a = 0.637R$
$l = 1.57R$

$$I_{xo} = \pi R^3$$
$$I_x = \pi R^3 + l(d_y)^2$$
$$I_{yo} = \pi R^3$$
$$I_y = \pi R^3 + l(d_x)^2$$

$$I_{yo} = \frac{\pi}{2} R^3$$
$$I_y = \frac{\pi}{2} R^3 + l(d_x)^2$$
$$I_{xo} = \left(\frac{\pi}{2} - \frac{4}{\pi}\right) R^3$$
$$I_x = \left(\frac{\pi}{2} - \frac{4}{\pi}\right) R^3 + l(d_y)^2$$

$$I_{xo} = \left(\frac{\pi}{4} - \frac{2}{\pi}\right) R^3$$
$$I_x = \left(\frac{\pi}{4} - \frac{2}{\pi}\right) R^3 + l\left(d_y\right)^2$$
$$I_{yo} = \left(\frac{\pi}{4} - \frac{2}{\pi}\right) R^3$$
$$I_y = \left(\frac{\pi}{4} - \frac{2}{\pi}\right) R^3 + l\left(d_x\right)^2$$

Fig. 8-6. Moments of inertia of various weld segments.

Examples